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ARMORED MEDICAL RESEARCH LABORATORY

FORT KNOX, KENTUCKY

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Second Partial Report

On

PROJECT NO. 37 - STUDY OF ERRORS IN FIELD ARTILLERY PRACTICE

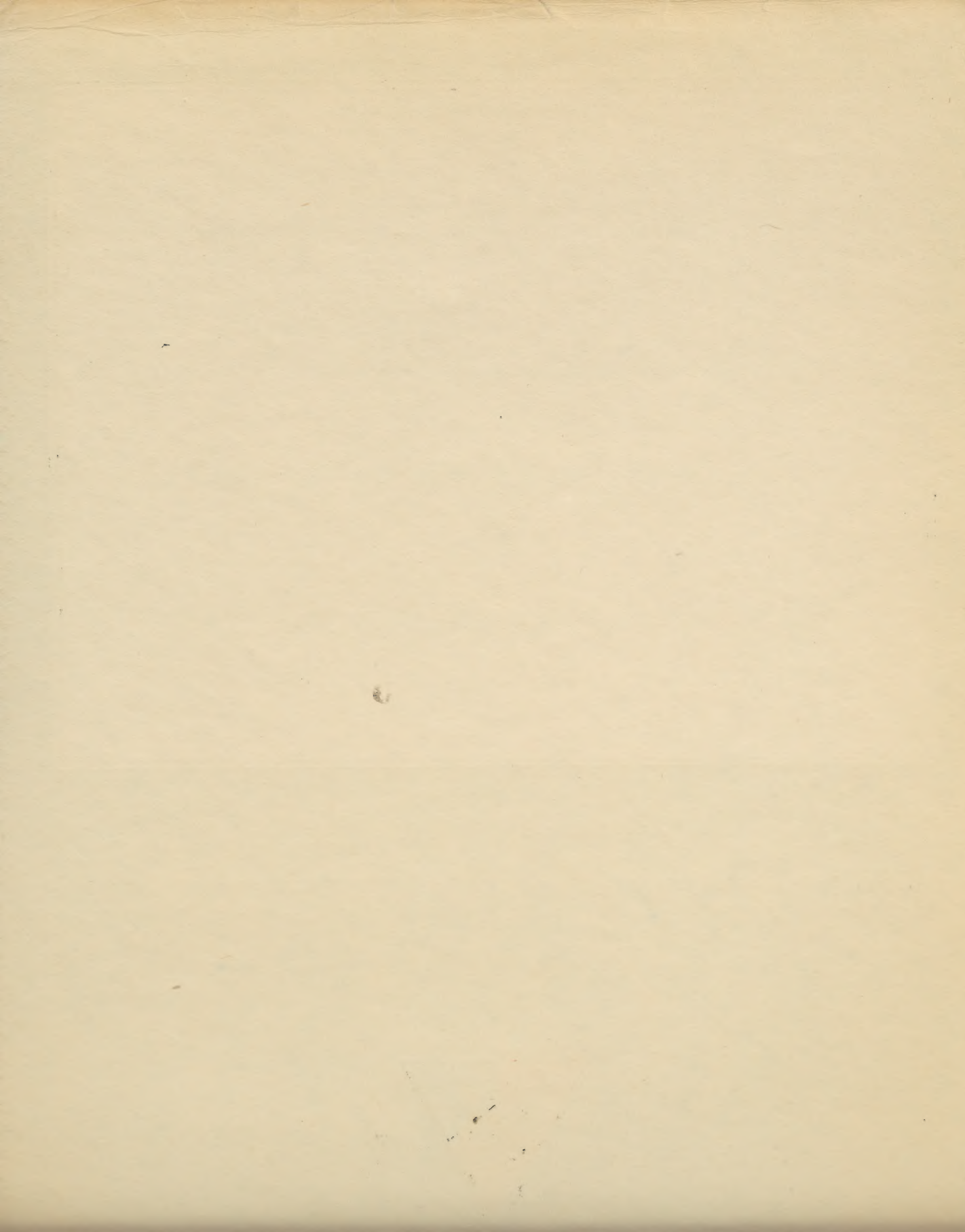
Subject: An Analysis of the Sources of Error in the Use of the
Panoramic Telescope M12 and Development of Principles of
Design for an Improved Instrument

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ARMORED MEDICAL RESEARCH LABORATORY
Fort Knox, Kentucky

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SECOND PARTIAL REPORT
ON
STUDY OF ERRORS IN FIELD ARTILLERY PRACTICE

1. PROJECT No. 37 - Study of Errors in Field Artillery Practice. Second Partial Report: Subject: An analysis of the sources of error in the use of the panoramic telescope M12 and development of principles of design for an improved instrument.

a. Authority: Ltr. AGF, 413.68 (R) (8 April 1944) GNRQT-10/78261 dated 8 April 1944.

b. Purpose: (1) To determine the principal causes of error in reading horizontal angles with the standard M12 panoramic telescope, to develop principles of design to eliminate such sources of error and incorporate these in a practical field instrument; (2) to study the nature and sources of errors in making deflection shifts and to indicate the essential requirements in design and performance of an improved gunner's aid.

2. DISCUSSION:

a. The panoramic telescope is well recognized as a source of errors in field artillery practice. In this connection, the 100 μ error is best known and its basic cause is generally recognized. Other errors of lesser and greater magnitude occur, however, and the causes of such errors must also be taken into account in any complete consideration of the problem of improving instrument design.

b. Based upon laboratory and field analysis, new instrument designs are presented which are shown to reduce the frequency of errors. The proposed improvements do not lend themselves to immediate field modification of existing instruments. They can, however, be introduced without any major changes in basic design of the present standard instrument, M12.

c. Design and operational requirements of the panoramic sight are discussed in Appendix I; the proposed modifications in design of the panoramic sight are presented in Appendix II and the results of field tests of a pilot model in comparison with the panoramic telescope M12 are summarized in Appendix III.

3. CONCLUSIONS:

a. The present standard panoramic telescope, M12, is subject to errors in use which arise from certain well-defined deficiencies in instrument design. The frequency of errors decreases with continued training and experience of the operators, but remains at a needlessly high level in trained groups. Moreover, the pattern of errors does not change significantly with training.

b. The major deficiencies of the azimuth scales on the present instruments are:

- (1) Continuous movement of the coarse scale relative to its index with rotation of the micrometer, resulting in uncertainty and confusion concerning the true hundreds value when the micrometer reading is in the danger zone just below 100 or above zero.
- (2) Inadequacies of design and numbering of both coarse and micrometer scales, requiring frequent interpolation in un-numbered portions.
- (3) Lack of sufficient definition and clarity of engraved lines and numbers on the scales.
- (4) Use of two separated scales, arranged in an order opposite to the normal order of reading the whole azimuth value.

c. A new design is proposed which eliminates these deficiencies. The proposed design is applicable to the present panoramic telescope without change in type of construction and without loss of rapid movement of the head; the only additional moving parts are those required for the gunner's aid.

d. The proposed design markedly reduces the frequency of errors in reading deflections—from approximately 13 per cent to less than 1 per cent of preselected angles read by a group of trained gunners and less experienced gun-crew members.

e. Analysis of the operational characteristics of the gunner's aid, supplemented by field tests, shows that the aid provided on the M12 panoramic telescope is inadequate and is not of great assistance in preventing errors in laying guns in deflection.

f. The essential characteristics of an adequate gunner's aid are presented and incorporated in the proposed new instrument design.

4. RECOMMENDATIONS:

That the proposed new flat dial type panoramic telescope described in Appendix II and the accompanying drawings (Figs. 4 and 7) be constructed in sufficient numbers in pilot form for field acceptance tests, such tests to evaluate the relative certainty of reading deflection and setting off deflection shifts in actual service practice, as well as to determine the ruggedness,

serviceability, etc., of the instrument.

5. ACKNOWLEDGEMENT:

This project is a joint undertaking with NDRC and the field tests reported herein were jointly conducted with the staff of NDRC, Project SOS-11, Dr. John P. Nafe, Director.

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APPENDIX I

INSTRUMENT DESIGN REQUIREMENTS

1. Errors in the use of the panoramic telescope may be considered, from the standpoint of instrument design, under two headings: (1) those arising in the reading of the main azimuth scales or in setting off specific base deflection values, and (2) errors made in the course of fire adjustment, during which the sight is shifted left and right in decreasing amounts, beginning with an initial large shift and continuing until the desired line of fire is achieved. Artillerymen have long recognized that the instrumental manipulation, reading of scales, and determination of the successive correct settings in fire adjustment, give a good deal of trouble to inexperienced personnel and that the acquiring of skill in the use of the panoramic telescope requires sound, continuing training. It is known that certain types of errors (e.g., the 100 μ error, and errors in direction) are most common. Definite training and operating procedures are prescribed in order to minimize the frequency of such errors. In peace time, the long training period and selection of gun-crew personnel served to offset the recognized deficiencies of the instrument. The demands of war, however, have made it impossible to rely mainly upon this procedure, and as a consequence, the need for a better instrument has become apparent. This does not refer to the optical qualities or basic accuracy of construction, but chiefly to the design of scales. In the hands of an experienced instrument user and given sufficient time, the scales are read correctly and without difficulty. An inexperienced operator, however, and even one skilled in the use of the instrument, when pressed for time or under stress, makes far too many errors. Because of the design and placement of the scales, the manner of reading the instrument is needlessly obscure. Furthermore, the scale design actually invites certain types of errors which must be constantly guarded against, even by experienced personnel.

An examination of the present and past models of panoramic telescopes reveals that no major changes have been made in scale design with respect to ease and certainty of reading. It is felt, however, that difficulties in this respect are not necessary and that improvements can be effected which will result in more direct and certain reading of the instrument and diminish the required training period. The time thus saved could be devoted more profitably to other phases of the problem of gunner training of greater fundamental importance.

2. Design requirements for main deflection scales.

a. The total deflection reading on the present standard instrument M12 (Fig. I) is obtained from two separate scales, a coarse scale on the central column of the instrument, graduated at 100 μ intervals and numbered every 4th value, and a fine or micrometer scale on the worm shaft which is graduated at 1 μ intervals and numbered every tenth. The scales are displaced from each other in a direction opposite to the normal direction of reading so that the two scale readings must be combined in reverse to give the total deflection value. The coarse scale moves relative to its index mark as the micrometer worm is rotated. Thus, as the micrometer value approaches 100, the index on the coarse scale approaches the next hundreds value and, in a poorly adjusted instrument,

may even pass the next graduation before the micrometer has reached 100. One must constantly make certain of the micrometer value, therefore, before reading the coarse scale. Further confusion in scale reading arises owing to the infrequent numbering of the scales and consequent interpolation which is required. Another potential source of error is the movable index mark on the micrometer. This is employed as the gunner's aid in making shifts and one must make certain that it is returned to its zero position before reading the deflection value. In addition to the confusion from improper scale design and placement, the lack of fineness and clarity of scale engraving and painting further contributes to the difficulty of reading.

b. Other designs of panoramic telescopes in current use, while they differ from the M12 in certain details, are similar to it in the employment of displaced and sparsely numbered coarse and fine deflection scales and have the same fundamental weaknesses arising from these features of design. The L5 sight (Fig. 2) has a flat micrometer dial which is easier to read than the drum micrometer on the M12 since the whole dial is seen at a glance. However, owing to the fact that this dial also serves as the gunner's aid scale (see paragraph 3 following) there is likelihood of error in deflection reading because of improper setting of the dial zero. The numbers and graduation marks on this dial are small and difficult to read. The coarse scale on the L5 is also difficult to read owing to its restricted view behind a window. The coarse and fine scales, as in the M12, are reversed in position from the normal direction of reading.

c. The German Rbl F 32 (Fig. 3), panoramic telescope differs from the M12 in two major respects: first, the scales are more sharply engraved, which together with the use of black letters on an off-white background, makes the instrument more easily read, and second, the coarse and fine scales are in the normal positions for reading from left to right.

d. The foregoing criticisms of the M12 and other panoramic telescopes are borne out by experience in their field use and, in greater detail, by the results of tests reported herein (Appendix III). By negation, the noted deficiencies serve to establish the essential features of design of the deflection scales in an adequate instrument, thus:

- (1) The hundreds value must be constantly correct, regardless of the micrometer position.
- (2) Minimum interpolation should be required in reading the scales.
- (3) The hundreds and micrometer values should be presented in close juxtaposition and in the normal order of reading.
- (4) Maximum view of scales to give visual sense of scale position.
- (5) There should be no confusion of the deflection scales with the gunner's aid.

e. In an ideal instrument, every deflection setting would be seen as a complete four-digit number presented in clear, readable form. There would be no need for scale interpolation and no question as to the correct relation between

the hundreds and micrometer scale values. This immediately suggests the use of a four-digit counter of the automobile odometer type attached to the micrometer worm shaft through suitable gears so as to indicate directly the units as well as the tens and hundreds in the total deflection reading. The transition from 9 to 10 and from 99 to 100 would take place within 1 μ , thus presenting deflection values of 0109, 1999, etc., in their correct form just as intermediate values, such as 1326, are presented. There are certain mechanical objections to the direct counter, however, which should be mentioned; first, an important feature of the panoramic telescope is the worm throw-out which permits rapid hand rotation of the instrument head when desired. This requires two independent scales to show the angular positions of the main column and of the worm--a requirement which is not met by the direct counter geared to the micrometer worm; second, the conditions of rugged field use make it undesirable to employ small moving parts for speed-up of the indicator; third, the counter must be fully housed to protect it against dust and wear. Because of these objections another approach has been followed in the present study (see Appendix II) which provides the same essential advantages as the direct counter without its disadvantages, that is, without loss of rapid movement of the hand and without the use of rapidly moving parts.

3. Design and operational requirements for gunner's aid.

a. Paragraph 2 considered the sources of error in use of the panoramic telescope as an angle measuring or deflection setting instrument. In actual firing practice, however, the sight is employed for such purpose to a minor extent as compared with its frequency of use in setting off deflection shifts. In the initial laying of the battery, in establishing base deflection and in the conduct of prepared fire, the main deflection scales are employed directly. For shifts in direction during adjustment of fire, however, the gunner's aid is commonly employed, and, since such shifts represent the vast majority of all manipulations of the panoramic sight in practice, it is evident that the operational characteristics of this device are of primary importance in determining the likelihood of errors in direction of fire.

b. Shifts may be left or right (requiring opposite rotation of the sight to effect proper direction of shift of the gun) and vary in magnitude from a minimum of 1 μ to a maximum determined by transfer limits or the limits in traverse of the weapon (approximately $\pm 500 \mu$ from center, for modern U. S. artillery pieces). In the typical problem, the initial shift from base deflection is frequently greater than 100 μ , the magnitude varying with decreasing frequency of occurrence up to 400 - 500 μ . Subsequent shifts in the course of fire adjustment are commonly less than 100 μ , decreasing in magnitude and alternating in direction as adjustment of fire progresses. The larger shifts are generally made to the nearest 10 μ or greater major scale value; individual shifts of 5, 2, and even 1 μ are made, however, in the latter stages of adjustment. In general, each shift is followed by the firing of at least one round by the adjusting piece, but on occasions a command is immediately followed by another without intermediate firing, thus requiring considerable speed in completing commands. The shifts are not necessarily alike on all guns of the battery, since control of width of the sheaf and convergence of fire on specific targets requires that the weapons depart from parallelism. Commands to open or close on the base piece by so many mils and even entirely different shift commands for

the four runs may be employed to secure the necessary adjustment of individual pieces.

c. In the course of making these varied shifts, the actual deflection setting on the panoramic telescope may not be referred to at all, full dependence being placed upon the gunner's aid for correct completion of commands. It is evident from this brief review that successful performance of the task requires clear thinking and quick response, and it is generally recognized that the assistance of an adequate gunner's aid greatly simplifies the operation, increases the speed of adjustment and reduces the likelihood of errors. An analysis of reported errors in service practice (see First Partial Report, 18 Sept. 44) showed that nearly two-thirds of the errors at the battery were mistakes in deflection. They varied in magnitude from 1 to 500 μ with 100 μ errors most common. It appeared from these data and from field observations that confusion in direction of shift, going left instead of right and vice versa, was the most common type of error; failure to make miscellaneous small shifts correctly was next and incorrect large shifts (accounting for most of the errors of 100 μ and greater) the third major cause of error. The question may be raised as to the specific contribution to this unsatisfactory situation which is chargeable to deficiencies in the design of the gunner's aid on the M12 panoramic telescope and to what extent it can be improved in function.

d. The design and operating characteristics of the gunner's aid is found to vary considerably in the various panoramic sights in present use. Typical designs which may be considered here are the U. S. Standard M12 (Fig. 1) and the older M5 (Fig. 2), and the German Rbl F 32, shown in Fig. 3.

e. Among these instruments, the M12 has a gunner's aid with the most limited characteristics. It consists in nothing more than a movable index mark on the micrometer scale together with an R and L to show proper direction of shift. The single micrometer scale is employed in setting off shifts as well as in its primary role of indicating deflection. The recommended procedure in completing shifts is as follows: the movable index is first moved to the nearest even 10 μ graduation on the scale and the shift is made by counting off on the scale as the micrometer is rotated, first the hundreds then the tens and finally the units. For example, assume the deflection reading to be 1857 and the desired shift to be L 285. The index is first moved to 60 on the micrometer scale and the micrometer rotated two full turns to 60 again, thus setting off 200 μ of the required shift. It is then turned through an additional 80 mils by counting the number of 10 μ graduations as they pass the index and finally set 5 μ beyond the last counted 10 μ graduation to complete the command (200 + 80 + 5). Returning the index to its zero setting gives the actual deflection value, which in the present example would be 2142. This procedure clearly requires close concentration on the task at hand as well as clear thinking and a good memory in order to complete the command in these distinct steps.*

* The deficiencies in this type of aid are well indicated by the fact that no common understanding exists among troops of its proper manner of use. Some artillery officers have even refrained from teaching its use because of evident feeling that it was inadequate.

f. The gunner's aid on the M5 panoramic telescope differs basically from the type just described. As will be seen in Fig. 2, a double scale of different colors is provided on the small flat micrometer dial; so its entire capacity of 100 μ can be seen at a glance. This dial scale can be rotated independently but does not turn with the micrometer worm. When the scale 0 is set opposite the fixed index mark, it serves to indicate the micrometer scale portion of the true deflection. In its use as a gunner's aid, however, the 0 is set against the index mark on the end of the worm shaft (see Fig. 2) and thus provides a direct scale of 100 μ capacity for setting off shifts. The proper directions of rotation for left and right shifts are indicated by arrows and the corresponding scales, in contrasting colors, run in opposite directions. The manner of use is clear. A shift of L 75, for example, is accomplished as follows: the scale is rotated until the zero is set against the worm index and the micrometer then rotated in the indicated direction until its index comes to 75 on the scale. For a shift of L 275, two complete turns are first made and then 75 set off on the scale. After completing a commanded shift, the scale is re-set with zero against the worm index, thus making ready for the next shift. If, at any time, the command to record deflection is ordered, the scale is quickly rotated to bring its zero against the fixed index and the micrometer value of the deflection reading obtained from the position of the worm index against the black figures on the scale.

g. It is evident that the performance characteristics of the M5 gunner's aid greatly exceed those of the M12 and much less thinking and step-by-step manipulation are required to complete shifts. Its superior features are (1) two scales of 100 μ , running in opposite directions for left and right shifts, the zero of which can be quickly positioned regardless of the actual micrometer deflection value, (2) the full scale is in view at all times so that the operator obtains a visual picture of relative position much as one experiences in reading a clock dial. The disadvantages of the M5 gunner's aid are (1) the small diameter of the dial and crowding of scales; (2) numbering of scales only at 10 μ intervals and thus requiring interpolation along the scale; (3) the use of two concentric circular scales for left and right with consequent danger of reading the wrong scale; (4) inability to set off shifts greater than 100 μ directly, necessitating two steps in completing large shifts. Mechanically, the M5 has another disadvantage frequently referred to in comparing it with other instruments, namely, owing to poor design of the friction clutch holding the scale it may move when the micrometer worm is rotated, or the scale is accidentally hit.

h. The gunner's aid on the German Rbl F 32 instrument represents a third type of design, having certain operational characteristics which may be advantageous and others of less value than those possessed by the M5. In this instrument (Fig. 3), the gunner's aid consists in two completely independent, movable scales corresponding to the coarse and fine deflection scales. For any deflection setting these may be rotated to zero and the shift, of any magnitude, made by direct reference to these scales.* Two adjacent micrometer scales of contrasting

* The gunner's aid on the British dial sight is similar in principle in that it has two completely independent coarse and fine scales (degrees and minutes) which may be zeroed at any deflection setting and thus permit the direct setting off of deflection shifts of any magnitude.

colors and running in opposite directions, are provided for left and right shifts and the coarse scale is similarly numbered from zero in the two directions up to 3200, with corresponding colors. The main advantage of this aid over that provided on the M5 is its unlimited capacity of shift without employing two-step manipulation. Another advantage is in the use of the movable scales completely independent of the primary deflection scales, thus completely eliminating the mechanical objections of the M5 scale. It has the same disadvantages as the M5 aid in that two adjacent infrequently numbered scales, running in opposite directions, are provided on the micrometer portion of the aid. A further disadvantage not found in the M5 is the limited view of the micrometer scale at one time (in this respect, similar to the M12). The adjacent positioning of two sets of scales, one for reading deflections and the other for making shifts, may also be a disadvantage since it introduces the possibility of reading the wrong scale.

i. The foregoing analysis of the function and operational characteristics of gunner's aid suggests the following as the essential features of such a device:

- (1) Direct reading of the total magnitude of the commanded shift, presented either in the form of the complete number, or requiring minimum interpolation on the scale.
- (2) Adequate capacity of aid to permit setting off shifts of any reasonable magnitude, at least up to 500 μ , without resorting to two-step manipulation.
- (3) Proper safeguards against 100 μ errors and other recognized deficiencies of scale design.
- (4) Clear indication of the correct direction of rotation in accordance with the command and two separate scales for left and right shifts.
- (5) Visual sense of amount of rotation required to set off the commanded shift and to re-set to zero and clear indication of the zero position.
- (6) Separation of the gunner's aid from primary deflection scales to avoid confusion; the aid to be attached to the sight-rotating mechanism by a positive-acting clutch requiring no manual locking.
- (7) Means for rapid return of the aid to its zero setting after the shift is completed.
- (8) **Maximum** readability of the numbers and scales.
- (9) Method of operation as simple and obvious as possible consistent with its functional requirements, thus requiring minimum training in its use.
- (10) Rugged construction.

APPENDIX II

DESIGN OF IMPROVED PANORAMIC TELESCOPE

PART I. FLAT DIAL TYPE

1. The proposed new instrument, shown in Fig. 4, possesses the essential characteristics with regard to design, certainty of reading and simplicity of operation which were considered in Appendix I. These improved features will be made clear in the description which follows:

a. Structural changes from M12 design. The proposed instrument employs the same optical system and internal gears and the same micrometer worm as the M12. The position of the worm relative to the eyepiece has been rotated 90° however, and the direction of throw-out reversed.* The micrometer dial and actuating knob are also reversed on the worm. The flat micrometer dial is located directly above the eyepiece and the micrometer actuating knob is in the rear. It will also be noted that the coarse scale is increased in diameter.

b. Deflection indication. The micrometer dial (A, Fig. 4), has a spiral edge which just clears the coarse scale face. Both dials are greatly enlarged over their M12 counterparts so that every hundreds value and every second micrometer value is numbered. Thus, no interpolation is involved in reading the hundreds and an interpolation of no more than 1μ is required in the determination of the micrometer value. The novel feature of this arrangement of scales is the position of the spiral micrometer dial masking the coarse scale, the purpose of which is to insure a constantly correct relation between the hundreds and micrometer scale values. The pitch of the spiral approximately equals the angular distance of 100μ on the coarse scale. Thus, during the revolution of the micrometer, its edge just keeps up with the movement of the hundreds value. As the micrometer rotates from 99 to 00, the break in the spiral passes the coarse scale and reveals the next higher hundreds value. The sequence of events is illustrated in Fig. 5 for a series of typical settings.

c. The following important features will be noted:

- (1) Hundreds and micrometer values are brought together so as to present the total deflection as a complete reading in one position and in the proper order.
- (2) Constantly correct indication of the hundreds value regardless of the micrometer position, thereby eliminating the cause of the 100μ error. Uniformity of graduations and accuracy of scale adjustment are not important in this respect.
- (3) No interpolation required on sparsely numbered scales.

* Although the throw-out mechanism shown is the same as in the M12, it is believed that the eccentric rotary throw-out mechanism employed in the German Rbl F 32 panoramic telescope would be better. Because the throw-out handle on the M12 is offset above the bearing arc, the twisting force causes uneven wear on the bearing and tends to bind and hinder the movement. This difficulty does not exist with the eccentric rotary throw-out.

- (4) Flat micrometer dial, partially exposed and thereby giving some visual sense of angular position.
- (5) Complete separation of gunner's aid from deflection scales to avoid confusion of reading and errors from improper index setting.

d. Gunner's Aid.

- (1) The gunner's aid consists in two dials mounted concentrically with the main micrometer disc. The larger dial (B, Fig. 4) carries two 100 μ scales, black and red in color, numbered every other value and running in opposite directions completely around its periphery. This dial is connected to the micrometer worm through a detent clutch and rotates directly with the worm. The second dial (C, Fig. 4) is graduated into sixteen equal spaces and carries two scales, numbered 0 to 7 and running in opposite directions on the two halves of its periphery. This auxiliary dial is geared to the micrometer through 16:1 gears* and detent clutch so that it rotates 1/16 revolution or one graduation for one complete turn of the micrometer worm. Thus, one graduation on the auxiliary dial is 100 μ and the total capacity of the gunner's aid is \pm 799 μ . A spiral mask (D, Fig. 4) mounted over the auxiliary dial, is geared to the micrometer worm through 1:1 gears* and thus rotates at the same rate as the worm, or once for every 1/16 turn of the auxiliary hundreds dial. This mask serves the same purpose as the spiral edge on the main micrometer dial in that through its motion it reveals at all times the correct hundreds value for all the micrometer positions. The transition between 99 and 00 μ is equally sharp so that no difficulty arises in determining the correct reading, as indicated by the illustrative positions in Fig. 6. The two scales on the main dial and the corresponding auxiliary dial scales are colored red and black and serve to indicate right and left shifts, respectively. The directions of rotation for right and left shifts are indicated by words and arrows in the proper colors. The manner of operation of the gunner's aid is as follows: With the instrument set at any deflection value, the two dials on the gunner's aid are brought to their zero positions, first, the 100 μ scale by rotating its knob (E, Fig. 4) and then the secondary dial by finger action against its knurled edge (F, Fig. 4). Since both dials are connected to the worm shaft through detent clutches they can be re-set to zero in this manner without causing the worm to rotate. The commanded shift is then set off by rotating the micrometer worm knob (G, Fig. 4) in the proper direction, as indicated on the aid, until the correct reading appears on the aid scale. A right or left shift of any magnitude up to 799 μ can be set off directly without resort to any mental arithmetic or multiple-step manipulation.

* Commercial gears are applicable since the accuracy of the instrument does not depend upon them.

For right shifts, it will be noted, the hundreds and corresponding micrometer scales are red. Similarly, for left shifts, the two black scales are employed. Immediately after completing shift the gunner's aid is again re-set to its zero position, thus making ready for the next command.

- (2) It may be noted that to re-set the aid to zero it is never necessary to rotate the micrometer aid dial more than one-half turn, regardless of the magnitude of the preceding shift since the auxiliary hundreds dial can be re-set independently after the micrometer dial has been positioned. To assist further in quick re-setting and also to give some visual sense of dial position, the flat dials of the aid are made as open as possible. Moreover, an arrow indicating the zero position is marked on the primary dial and on its re-set knob so that the amount of angular motion required to bring the dial back to zero is determined at a glance. An arrow is also provided for this purpose on the auxiliary hundreds dial. The detents on the two dials are, of course, spaced in accordance with the dial graduations.

e. Base deflection indicators. A new feature of this sight is the provision of base deflection indicators (H, J, Fig. 4). These are in the form of friction rings mounted with the hundreds and micrometer deflection scales. For any base deflection setting of the instrument the indicators may be set to the proper positions on the two scales where they will remain during any subsequent rotation of the sight. When it is desired, later, to return the instrument to base deflection it is necessary only to shift the setting until the indicator marks on the rings return to their "zero" positions. The indicator rings can be added to the instrument without sacrifice of other essential features and may properly be included for the convenience of the gunner.

f. Structural Features.

- (1) All dial and scale faces are white or near-white in color and diffusely reflecting. The numbers are black on the deflection scales and black or red on the gunner's aid. Engraving of graduation and numbers must be sharp and the color applied carefully to insure high clarity. This is important since it contributes markedly to the ease and certainty of reading.
- (2) A throw-out lever (K, Fig. 4) is located for convenient operation below the micrometer dial.
- (3) Shields (L, Fig. 4) are provided over the micrometer and primary gunner's aid dials to protect them against finger contact when setting the base deflection indicator ring (J) and the hundreds dial on the gunner's aid.
- (4) The gears in the gunner's aid are housed and sealed against dust and rain.
- (5) The suggested fitting and inter-relation of moving parts are presented in detail in Fig. 7.

PART II. MODIFIED M12 SIGHT

2. Owing to the fact that the flat dial type instrument represents a basic departure from the M12, another improved design is presented which may be constructed by relatively simple modification of the M12. Whereas the flat dial type instrument is recommended for primary consideration, the modified M12 design is also presented to show that the same basic principles of design can be applied to it with essentially the same benefits. The modified instrument, as constructed for field test (Appendix III), is shown in Fig. 1, and the final design of the gunner's aid in Fig. 8. All modifications are external and can be made without disassembling the instrument or disturbing the optical system, internal gears or throw-out mechanism.

a. Deflection Indication.

- (1) The coarse scale is increased in diameter to permit numbering every hundreds value and is covered with a mask which reveals only one number at a time. The enlarged deflection micrometer drum which replaces the right-hand micrometer knob on the M12, has a spiral edge against which a mask actuating lever bears. Thus, the mask rotates at the same speed as the coarse scale, when the micrometer is turned and, as a consequence, the correct hundreds value, except in the transition zone, is continuously shown, regardless of the micrometer position. The mask starts to shift to the next higher hundreds value when the micrometer passes 96 μ and the shift is just completed when the micrometer reading is 00. For the three intermediate micrometer settings 97, 98 and 99, the mask is undergoing rapid shift and the hundreds value no longer coincides with the index mark on the mask. This warning, together with the increased friction during the shift, serves as a warning with respect to the reading in the transition zone. This order of events is reversed when the instrument is rotated to a lower deflection setting. The method of relating the coarse and fine scales employed here was shown in field tests (Appendix III), to reduce to a minimum the likelihood of occurrence of the 100 μ error. The continuous numbering of the coarse scale and alternate numbering of the micrometer drum eliminate the necessity for scale interpolation which, in turn, reduces the frequency of 200 μ errors and of small errors in reading the micrometer (Appendix III). Some benefit comes, also, from the normal left to right positioning of the coarse and fine scales.
- (2) Base deflection indicators are provided in the modified instrument.

b. Gunner's Aid. The gunner's aid on the pilot model (Fig. 1) was found in field tests to have certain structural and mechanical deficiencies, as follows:

- (1) Lack of positively fixed left-hand knob for instrument operation.

- (2) Inadequate functioning of detent or clutch to prevent disturbance of the micrometer worm when re-setting the aid to zero.
- (3) Scales not open and thus no opportunity for orientation in scale reading nor assistance in approaching zero during re-setting.

c. These deficiencies are largely corrected in the recommended design of gunner's aid for the modified ML2 panoramic telescope shown in Fig. 8. The aid is located on the left and is thus completely independent of the deflection scales. The enlarged micrometer drum (A) carries two 100 mil scales, black and red in color, numbered every other value and running in opposite directions for left and right shifts. An auxiliary dial (B) connected by spur gear to the micrometer worm, also carries two scales indicating left and right shifts in hundreds of mils. The auxiliary dial is located partly inside the hollow micrometer drum (I) so that the spiral edge of the latter bears approximately on the auxiliary dial and thus reveals the correct hundreds value at all positions of the micrometer with the same sharp transition from 99 to 00 as in the flat dial type instrument. The total capacity of the aid is right or left 500 mil and red and black numbering is employed on the main and auxiliary scales to indicate shift values in the two directions. The directions of rotation to effect right and left shifts are indicated by arrows and the letters R and L. Both the micrometer and hundreds dials are connected to the micrometer shaft by detent clutch and are therefore quickly re-set to zero without changing the instrument setting, suitable knurled ring and knob (C, D) being provided for the purpose. It will be noted that the left-hand knob (E) is attached rigidly to the micrometer worm for direct rotation of the sight and is not part of the gunner's aid. This meets the field practice requirement of sight operation by the left hand simultaneously with gun traversing with the right hand.

APPENDIX III

FIELD TESTS

1. Errors in Deflection Measurement in relation to scale design.

a. The relative performance of the pilot model of the modified panoramic telescope (Fig. 1) as compared with the standard M12 instrument, in the hands of both trained, and less-experienced, gun crew members was investigated at the Field Artillery School, Fort Sill. Tests consisted in the measurement of a series of twenty horizontal angles, varying from $>100^\circ$ up to $>3100^\circ$ and well distributed with respect to position on the coarse and fine scales. For these measurements a total of 96 test subjects, drawn from School troops, were employed. They included twelve battery executives (Lieutenants), thirty-six gunners and 48 No. 1 gun crew members. Periods of training in the field artillery varied for the group from three to thirty months. Four panoramic sights were compared: the standard M12 (see Fig 1), an M12 with a modified coarse scale*, the German instrument (see Fig. 3) Rbl F 32 and the AMRL pilot instrument (see Fig. 1) described in Appendix II. The German instrument was included in order to evaluate certain of its design features which differ from those found in the M12 instrument. The four sights were mounted on 105 mm howitzers approximately evenly spaced at 15 yard intervals in an open field. A series of twenty-one stakes were placed along a semi-circle of approximately 100 yards radius and carefully positioned by an Aiming Circle at the No. 2 gun location to give a pre-determined series of twenty angles from the zero stake; for each of the other three guns similar series of 20 angles were obtained which did not differ markedly in value from the pre-selected group. The distribution of angular values for the four gun positions was such that there was no marked weighting of values at any given position on the coarse or micrometer scales. The magnitude of shifts between successive angles was great enough, however, to encourage use of the free rotation of the prism head. Each man of the test group measured the twenty angles with each of the four sights from at least three different gun positions. The Lieutenants and gunners were employed in three groups of 16 in the mornings and the No. 1 men in similar groups in the afternoons. Each group of 16 men was divided into four sub-groups selected so as to give approximately equal distribution by AGCT scores within the four sub-groups. At the outset of each test period the four groups were assigned to the four different sights and remained at their assigned positions until all four men had measured the twenty angles, after which the groups shifted. This was continued until each group had used each sight. Owing to the fact that the German instrument was not available during the first morning and also because of obscuration of one stake from guns 2 and 4, the total number of angles read was not the same for all sights. The totals, together with the number of errors per 1000 readings are given, however, in each case in the tables of results presented below. The order of reading the angles,

* To be reported on under Project SOS-11 of NDRC

the schedule of rotation of subjects from one sight to another and the rotation of sights among the four gun positions during the six test periods were all suitably altered from one period to another so as to equalize as much as possible all variables not under study. Only minimum instruction was given to the men on the method of operation of the German* and AMRL sights. In the case of the AMRL sight, the men were simply told of the rapid mask movement on the coarse scale for micrometer values between 96 and 00 and that for all other micrometer positions the coarse scale value directly over the index mark should be read.

b. Results.

The number of errors in reading with the different sights are summarized in Tables 1 and 2. Errors of $\pm 100 \mu$ with the M12 sight are further broken down for study in Fig. 9. The comparative numbers of errors with the three instruments indicate that outstanding improvement was obtained with the AMRL instrument, and to a lesser extent, with the German sight.

2. Results with Standard Panoramic Telescope, M12.

a. Considering errors from all sources and of all magnitudes, the percentage of incorrect readings with the M12 was approximately 7% for the experienced group and 12% for all test subjects. Analysis of the errors in respect to source brings out clearly the deficiencies in scale design. For example, the errors less than 100μ recorded for the M12 (Table 1) are directly traceable to the confusion arising out of the necessity for constant interpolation along the sparsely numbered micrometer scale together with the fact that only a limited portion of the scale is visible at a time. In sharp contrast, the relatively few errors committed by the same group of subjects with the AMRL instrument demonstrates clearly the advantage of frequent numbering and minimum interpolation on the scale.

b. Deficiencies in scale design and the disadvantages of the displaced coarse and fine scales on the M12 are further emphasized by the number and source of 100μ and greater (Table 2). The relative frequency of occurrence of 100μ errors is seen in Fig. 9 to vary widely, depending upon the position of the micrometer scale for the angle being measured. Beginning with negligible occurrence in reading angles having micrometer values at the center of the scale, the likelihood of 100μ errors increases regularly as the micrometer position shifts toward zero or 100 with a sharp increase within the 10μ increment, 90-100, where more than one-third of all readings were in error by 100μ . It will be noted that most of the errors in the 90-100 μ interval are positive. This is in accordance with expectations in view of the primary cause of 100μ errors, namely, close juxtaposition of the coarse scale index mark with the next higher hundreds value when the micrometer value approaches 100. In fact, the distribution of positive errors in relation to the entire micrometer scale is in good agreement with this common explanation of the 100μ error. An interesting and unexpected finding, however, is the considerable number of negative errors and their relatively symmetrical distribution of occurrence along the micrometer scale. A possible

* The gunner's aid scales (see Fig. 3) were masked out since they were not under test and might have caused confusion.

TABLE 1

ERRORS IN READING DEFLECTIONS WITH PANORAMIC SIGHTS
 NUMBERS OF ERRORS <100 μ PER 1000 READINGS WITH THREE DIFFERENT SIGHTS

(Approximately 1500 Readings per Sight)

TYPE ERROR	NO. ERRORS PER 1000 READINGS					
	EXPERIENCED MEN (56)			LESS EXPERIENCED MEN (48)		
	Standard M12	German Rbl F 32	AMRL Pilot	Standard M12	German Rbl F 32	AMRL Pilot
$\pm 5 \mu$	7	-	1	14	3	-
$\pm 10 \mu$	8	2	-	3	2	-
Wrong Side of Maj. Grad.	7	2	1	15	2	-
Nearest Maj. Graduation	1	2	-	1	2	-
Transposed Figures	1	-	-	-	-	-
Miscellaneous*	-	2	-	5	2	2
Totals	24	8	2	38	11	2

* Varied in magnitude from 15 μ to 90 μ

TABLE 1

TABLE 2

ERRORS IN READING DEFLECTIONS WITH PANORAMIC SIGHTS
 NUMBERS OF ERRORS 100 μ OR LARGER PER 1000 READINGS WITH THREE DIFFERENT SIGHTS*

(Approximately 1500 readings with each sight)

TYPE ERROR	NO. ERRORS PER 1000 READINGS					
	EXPERIENCED MEN (56)			LESS EXPERIENCED MEN (48)		
	Standard M12	German Rbl F 32	AMRL Pilot	Standard M12	German Rbl F 32	AMRL Pilot
100 μ , plus or minus	17	8	5	113	13	1
>100 μ , plus or minus	14	-	-	5	-	-
>100 μ , but corrected	7	10	4	25	6	3
Left out digit	-	-	-	8	-	-
Totals	38	18	9	151	19	4

* After an initial training period of four readings

TABLE 2

explanation of the negative errors is that they represent over-compensation for the training which emphasizes guarding against errors when the micrometer is in the danger zone, and resulting in these tests, perhaps, in reading the coarse scale correctly but then subtracting 100 μ in accordance with this training.

c. A total of ten errors 200 μ in magnitude (per 1000 readings) were noted in the angular measurements with the M12. Unlike the 100 μ errors, these were not related to the position of the micrometer scale and therefore do not arise from the same source. A breakdown indicates that they are primarily associated with the design of the coarse scale; thus, one-half occurred in measuring angles within one coarse scale unit ($\pm 100 \mu$) of a numbered value and incorrectly reading on the wrong side of this major graduation, e.g. reading 996 for 796. The others, all negative errors, resulted from reading the nearest numbered value to the left on the coarse scale, or from the confusion of interpolation in the unnumbered section of the coarse scale. The few errors greater than 200 μ in magnitude are probably attributable to carelessness but do, nevertheless constitute an indictment of the instrument design which permits their occurrence.

3. Performance of German Panoramic Telescope Rbl F 32.

a. In view of the repeated evidence in these and other tests of weakness in scale design, and particularly, the use of two displaced scales in the M12 panoramic telescope, the relatively fewer errors made with the German sight are of considerable interest. This instrument also makes use of two separate scales and its micrometer is numbered in the same fashion. Despite these facts, and in the absence of any previous experience on the part of the test subjects with the German sight, only one-quarter as many errors were made. Undoubtedly, the interest of the test subjects in this enemy instrument accounts, in part, for its relatively superior showing. It is also true, however, that the instrument possesses certain inherent qualities which should be emphasized in the evaluation of the comparative results. Among the superior features of the instrument are:

- (1) Greater sharpness and clarity of engraving of lines and numbers on both coarse and fine scales and finer quality of workmanship.
- (2) Coarse scale numbered every second value with shorter lines to indicate intermediate values.
- (3) Micrometer on the right, so that total azimuth is obtained by reading from left to right.
- (4) Use of black lines and numbers on light background.

These features alone do not provide sufficient safeguard against errors to bring about all the improvement that is desired in a panoramic telescope. However, the favorable findings support the recommended new design since it, too, possesses these same advantages together with others of more fundamental character. Particular attention is called to the demonstrated advantage of sharpness and clarity of engraving of scales and fineness of construction.

4. Comparative results with Pilot Model of AMRL Panoramic Telescope.

a. Results of tests with the AMRL sight indicate that the principal sources of error in the M12 instrument, considered above, have been largely eliminated. The advantage derived from minimum interpolation on the micrometer scale has already been mentioned. In these tests the number of small errors (less than 100 μ) was 2 per 1000 readings as compared with 31 per 1000 approximately equal numbers of measurements with the M12.

b. Comparative results in respect to errors of 100 μ and greater are equally striking. No errors greater than 100 μ in magnitude were made with the AMRL sight, whereas 10 such errors per 1000 readings occurred with the M12. The total number of these large errors with the AMRL sight was 9 and 4 per 1000 readings for the experienced and less experienced men respectively as compared with 38 and 151 for the same men using the standard M12. The relative ease and rapidity of training in the use of the AMRL instrument is seen in the comparative percentage of recorded errors which were detected by the test subjects and voluntarily corrected before passing to the next measurement. Thus, of the remaining errors after the initial training period, one-half were corrected in the case of the AMRL sight, whereas only 1/6 were caught in the use of the M12. It is also of interest to note that the time required to complete the measurement of 20 angles was slightly less with the experimental AMRL instrument than with the M12 sight, the average times being 6½ and 7 minutes, respectively.

5. Summary.

a. The field tests show that the present standard panoramic telescope M12 possesses certain inherent weaknesses in design which contribute seriously to errors in use of the instrument and that the likelihood of occurrence of such errors is high*.

b. Comparative experience with the AMRL experimental sight, which was developed specifically to eliminate these weaknesses, shows that they are correctable with consequent marked improvement in performance from the standpoint of errors. It is also shown that the amount of training required to acquire skill in the use of the proposed instrument is small.

c. These improvements are gained without the addition of moving parts and without loss of the rapid rotation feature of the instrument head, which is employed in making large shifts of line of sighting. Although the findings of this study are based upon an experimental instrument which differs in some respects from the final proposed design, there is little doubt of equal success with the latter, which possesses the same advantages together with others not found in the experimental model, viz:

- (1) Reads from left to right—proposed design has the added advantage of bringing the four digits of the total azimuth value together in the visual field.

* The frequency of errors in the present study does not necessarily indicate the absolute frequency in combat firing owing to the artificial manner of test. The pattern of errors, however, may be considered significant with respect to relative certainty of reading with the several instruments.

- (2) Minimum interpolation on scales--none on coarse scale and only every other value on micrometer.
- (3) Continuously correct hundredths value for all positions of the micrometer, with rapid shift within 1 μ , rather than 4 μ as in the experimental model.
- (4) No additional moving parts since the mask movement employed in the pilot instrument is replaced by a spiral micrometer dial bearing directly on the coarse scale mount.

6. Errors in setting deflection shifts.

a. The operating characteristics of the gunner's aid on the pilot AMRL sight were compared with those of the M12, M5 and German Rbl F 32 in a series of tests at FAS, Fort Sill. These were preliminary tests, carried out for the purpose of securing further experience and information upon which to base the final design of the proposed gunner's aid. The four sights were mounted on a battery of Bishop trainers (accurate compressed air guns) and approximately 3000 "rounds" fired by repeating a series of 20 predetermined problems, using for the test 32 subjects--chief of sections and gunners--from FA School Troops. The tests were conducted in a building at a range of 23 yards against a target in the form of a mil scale graduated in 10 μ intervals. The correct position of fall on the target was known for every round fired and thus an observer was able to detect the occurrence of every error and note its magnitude. At the end of each problem and at irregular intervals, during firing, instrument deflections were checked. All fire commands were given by the men's own battery executives, while observers noted and recorded the manner of operation of the gunner's aids, speed of operation and general reaction of the men to the several instruments, as well as occurrence and kind of errors made. In general, about 1½ hours of instruction and practice preceded the tests.

b. The total number of errors made in these tests was so small that significant comparisons are difficult to make. Of considerable interest was the superior performance of the M5 sight as compared with the M12, which replaced it as the standard instrument. The four times greater frequency of errors with the latter (total errors 9 and 35 respectively) confirmed the poorer showing expected of it because of its more limited characteristics*. For example, the advantage of the full-face dial with clearly marked separate scales for left and right shifts accounts, perhaps, for the fact that no R-L errors were made with the M5, whereas 11 were made with the M12. Mistakes in scale reading were 4 and 12 respectively, while miscellaneous errors were 11 in number with the M12, compared with 3 for the M5. Two 100 μ errors were made with the M5 and 1 with the M12.

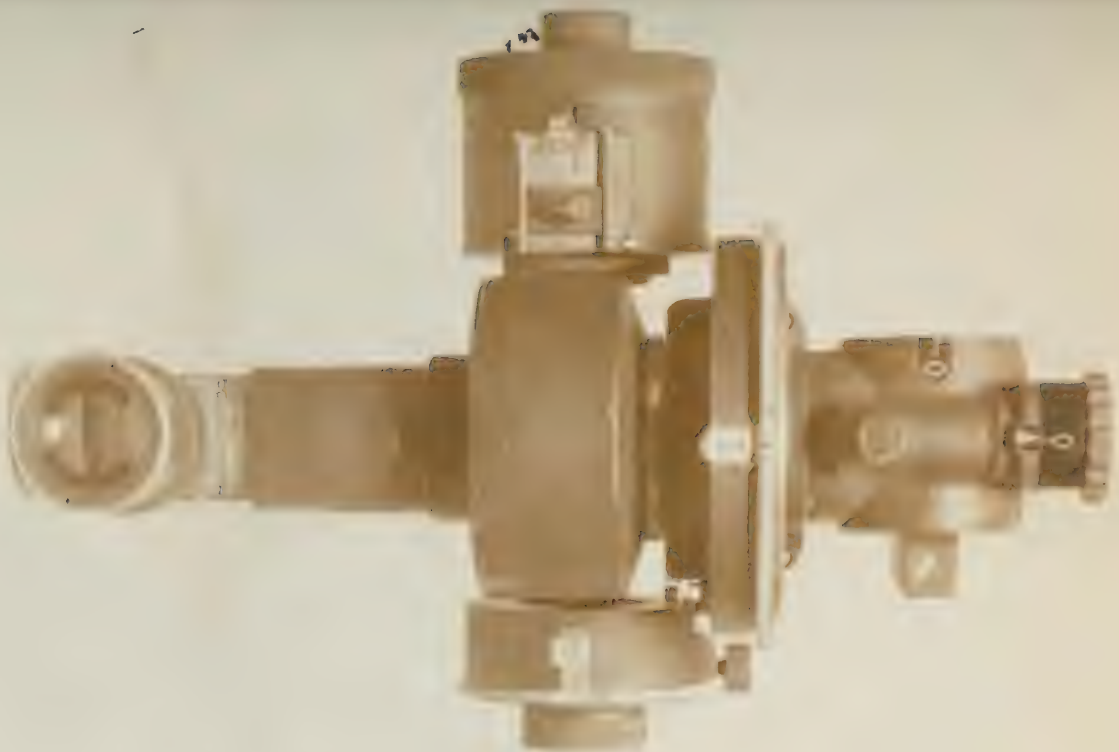
c. The performance of the gunner's aid on the pilot model AMRL instrument was not satisfactory owing largely to mechanical difficulties, lack of familiarity with it and relative difficulty of reading the scales. One 100 μ error, traceable to the gunner's aid, was noted and a considerable number of miscellaneous errors occurred which were attributable mainly to poor

* Subjects were, however, initially trained in the use of the M5 and had only recently acquired experience with the M12.

mechanical performance of the locking mechanism between the aid and the micrometer worm coupled with the fact that the left-hand knob was regularly employed in manipulating the sight. Failure to lock the aid securely or to unlock it before attempting a shift and use of the left-hand knob to make shifts when the aid was not securely clutched to the worm shaft caused slipping with consequent error in setting.

d. Another practical limitation revealed by these tests was the relatively time-consuming necessity for rotating the aid back through the total of the immediately preceding shift in order to reset to zero. In contrast, with other instruments it is necessary to rotate the aid no more than one-half turn. Considerable difficulty was also experienced in finding zero, owing to the limited portion of the scale seen within the mask. This restricted view of the scales also gave the operator no visual sense of the amount of rotation required to complete a given shift—a feature notably possessed by the M5 instrument. The readability of the gunner's aid also proved to be low.

e. The practical deficiencies of the gunner's aid revealed by these tests were considered in the re-design and it is believed that the essential features of an adequate aid have been incorporated in the proposed new instrument, described in Appendix II. It will also be noted in Appendix II that a similarly improved aid has been designed which is applicable in the modification of the standard M12 panoramic telescope, along the lines suggested by the pilot model employed in this study.





M5 PANORAMIC TELESCOPE

ARMORED MEDICAL RESEARCH LABORATORY
FORT KNOX, KY.

Project No. 37

Figure 2



GERMAN No. 1 F 32 PANORAMIC TELESCOPE
ARMORED MEDICAL RESEARCH LABORATORY
FORT KNOX, KY.

Project No. 37

Figure 3

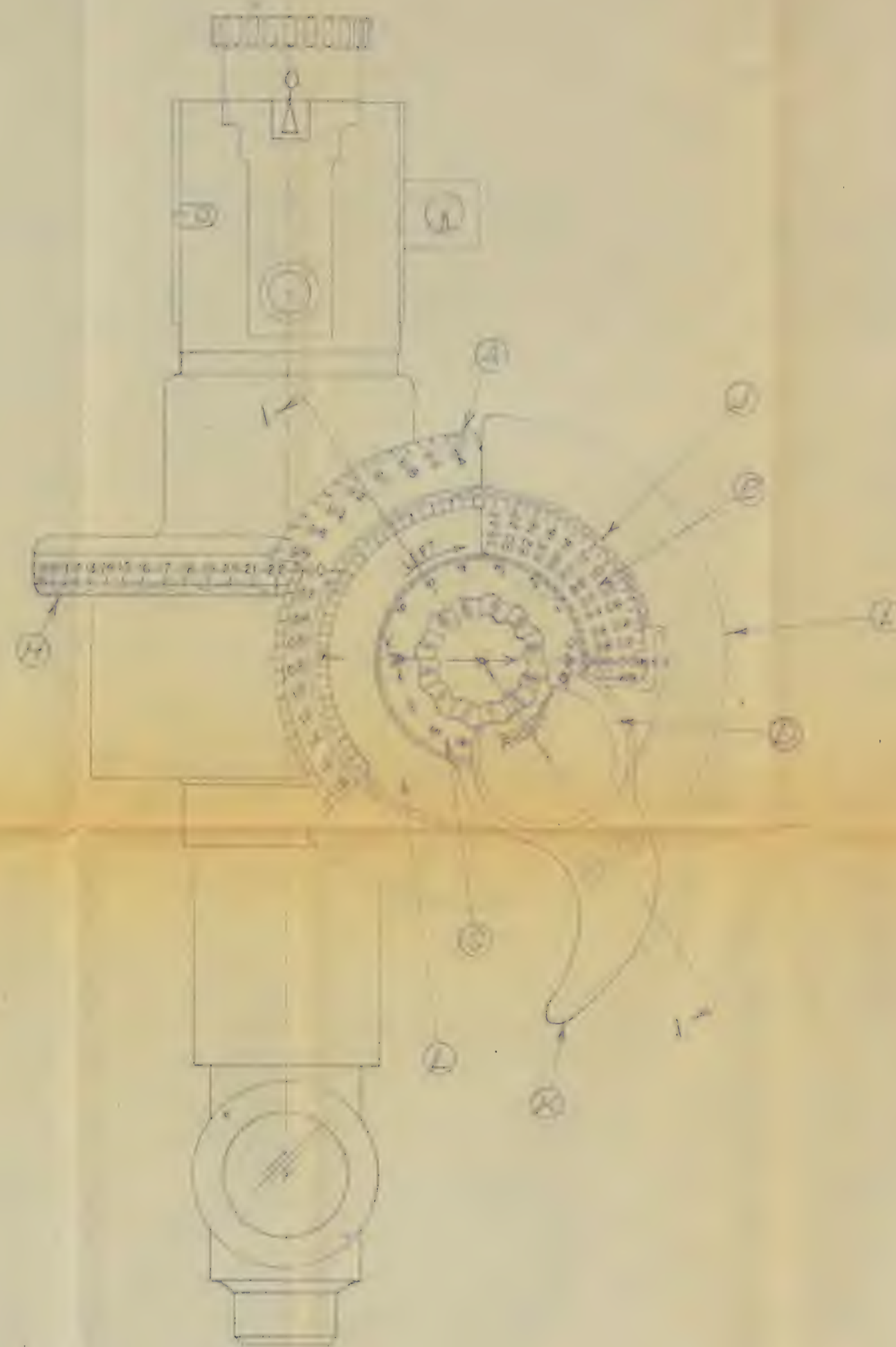
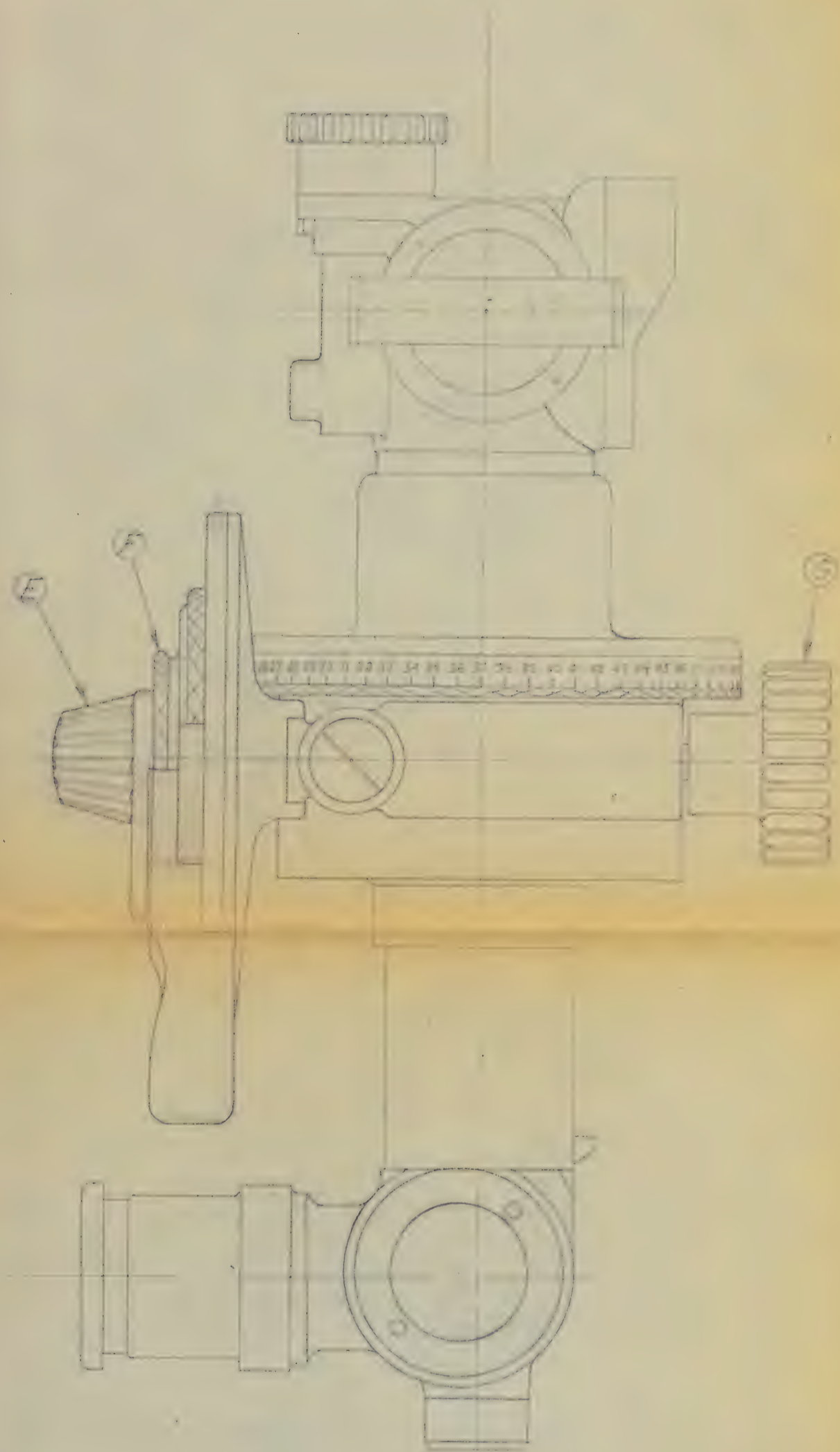
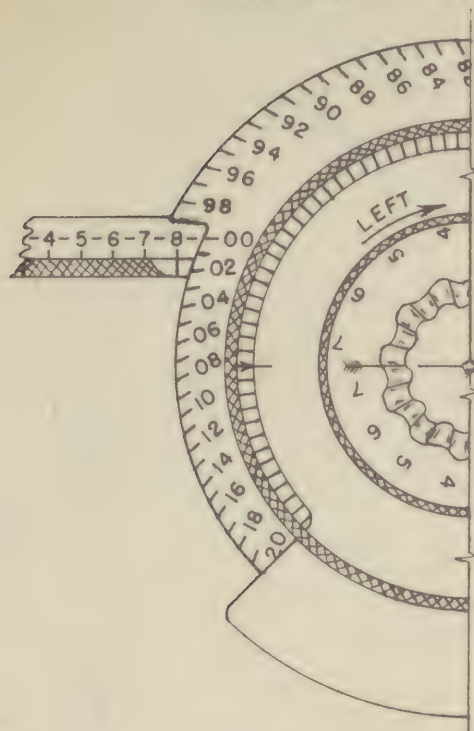


FIG. 4

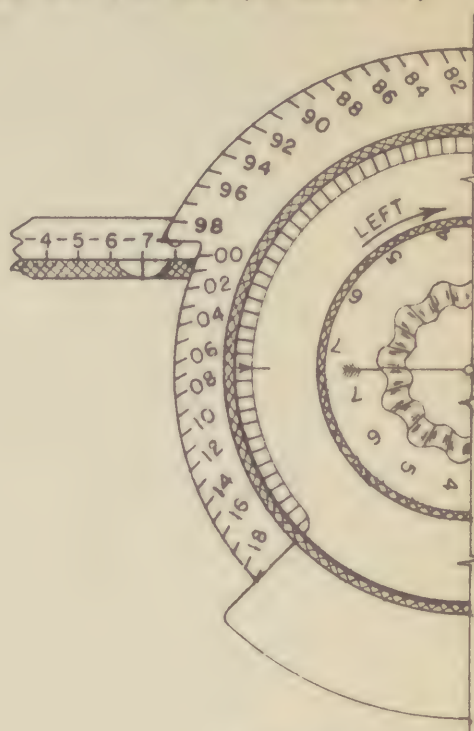
FLAT DIAL TYPE PANORAMIC TELESCOPE (FRONT AND SIDE VIEWS)	
ARMORED MEDICAL RESEARCH LABORATORY FORT KNOX, KENTUCKY	
Lt Col. F. S. BRANNETT	
SCALE FULL	DATE MARCH 22 1940

FIG. 5

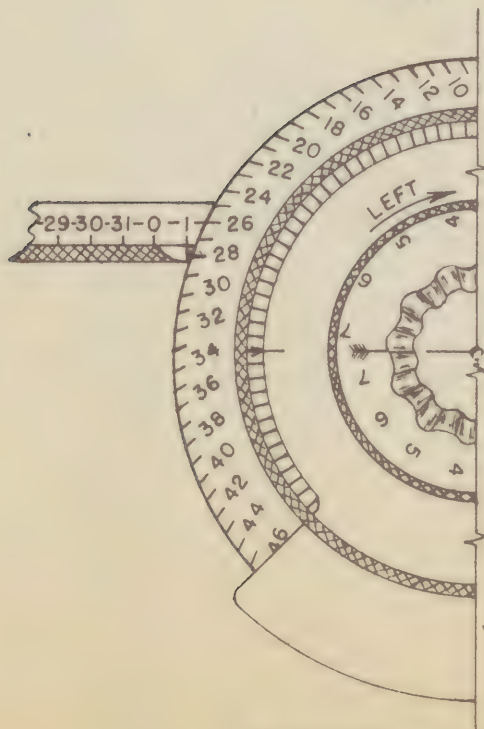
TYPICAL DEFLECTION SETTINGS
SHOWING RELATION OF COARSE AND MICROMETER READINGS
AND SHARP TRANSITION FROM 99 TO 00 (A AND B)



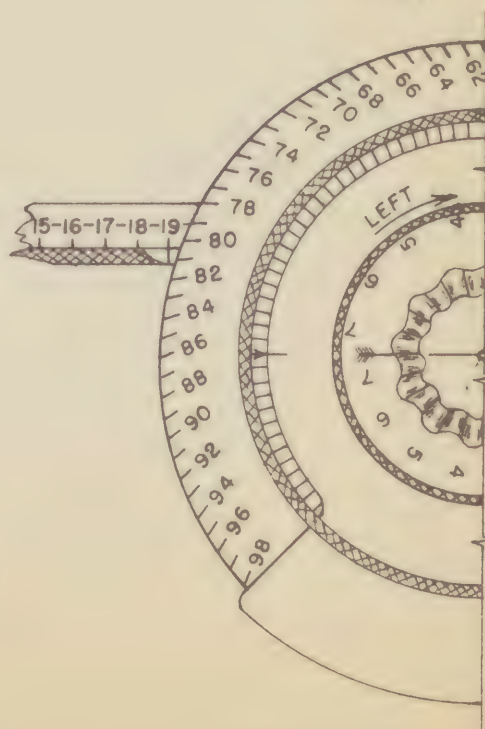
DEFLECTION = 800 η
(A)



DEFLECTION = 799 η
(B)



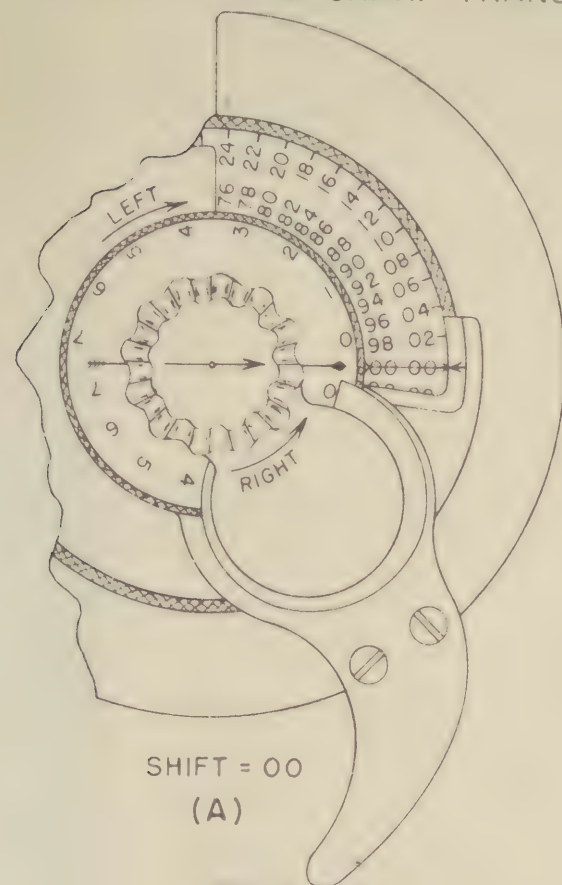
DEFLECTION = 126 η
(C)



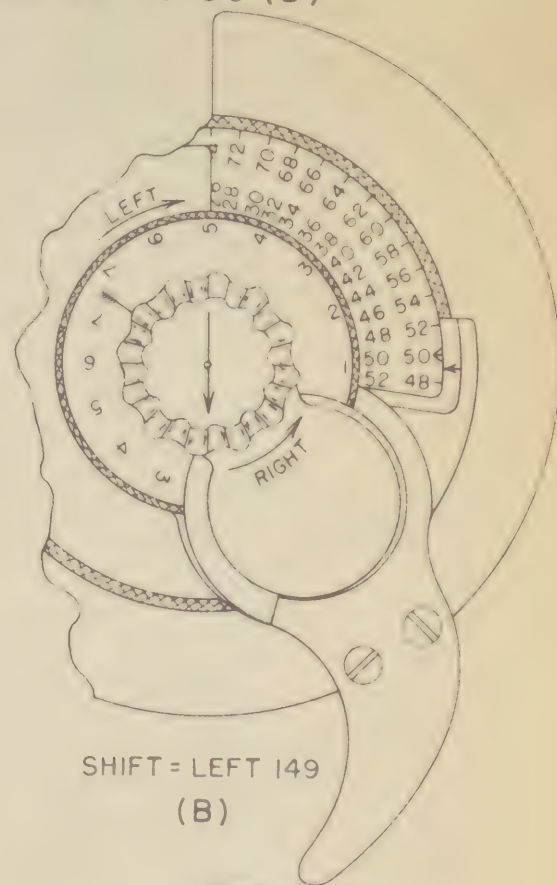
DEFLECTION = 1979 η
(D)

FIG. 5

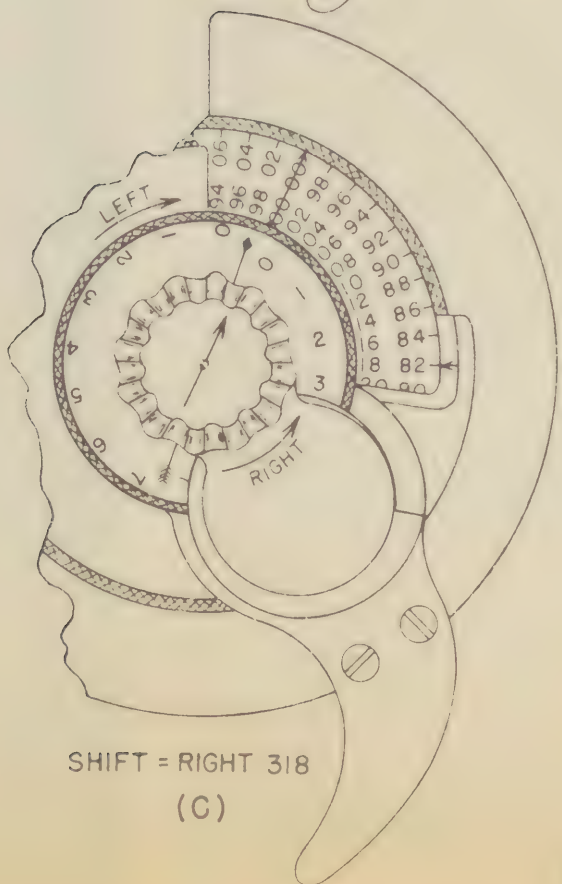
FIG. 6
 TYPICAL GUNNER'S AID SETTINGS
 SHOWING ZERO SETTING (A), LEFT AND RIGHT SHIFTS (B AND C)
 AND SHARP TRANSITION FROM 99 TO 00 (D)



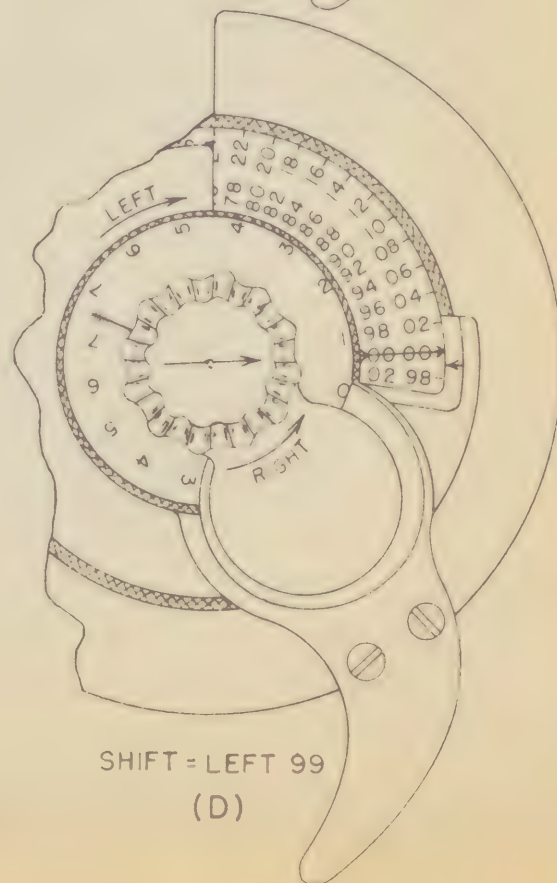
SHIFT = 00
 (A)



SHIFT = LEFT 149
 (B)



SHIFT = RIGHT 318
 (C)



SHIFT = LEFT 99
 (D)

FIG. 6

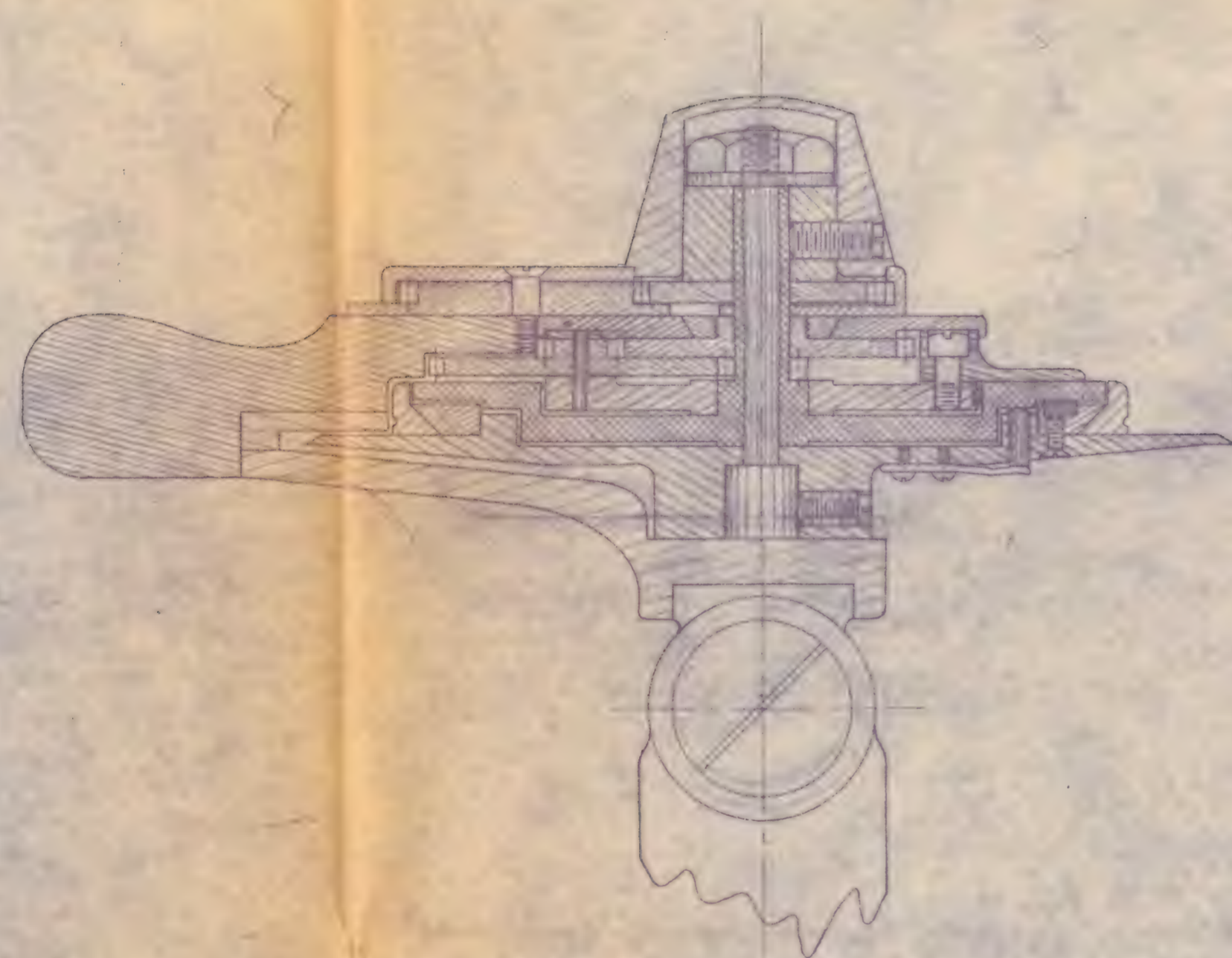
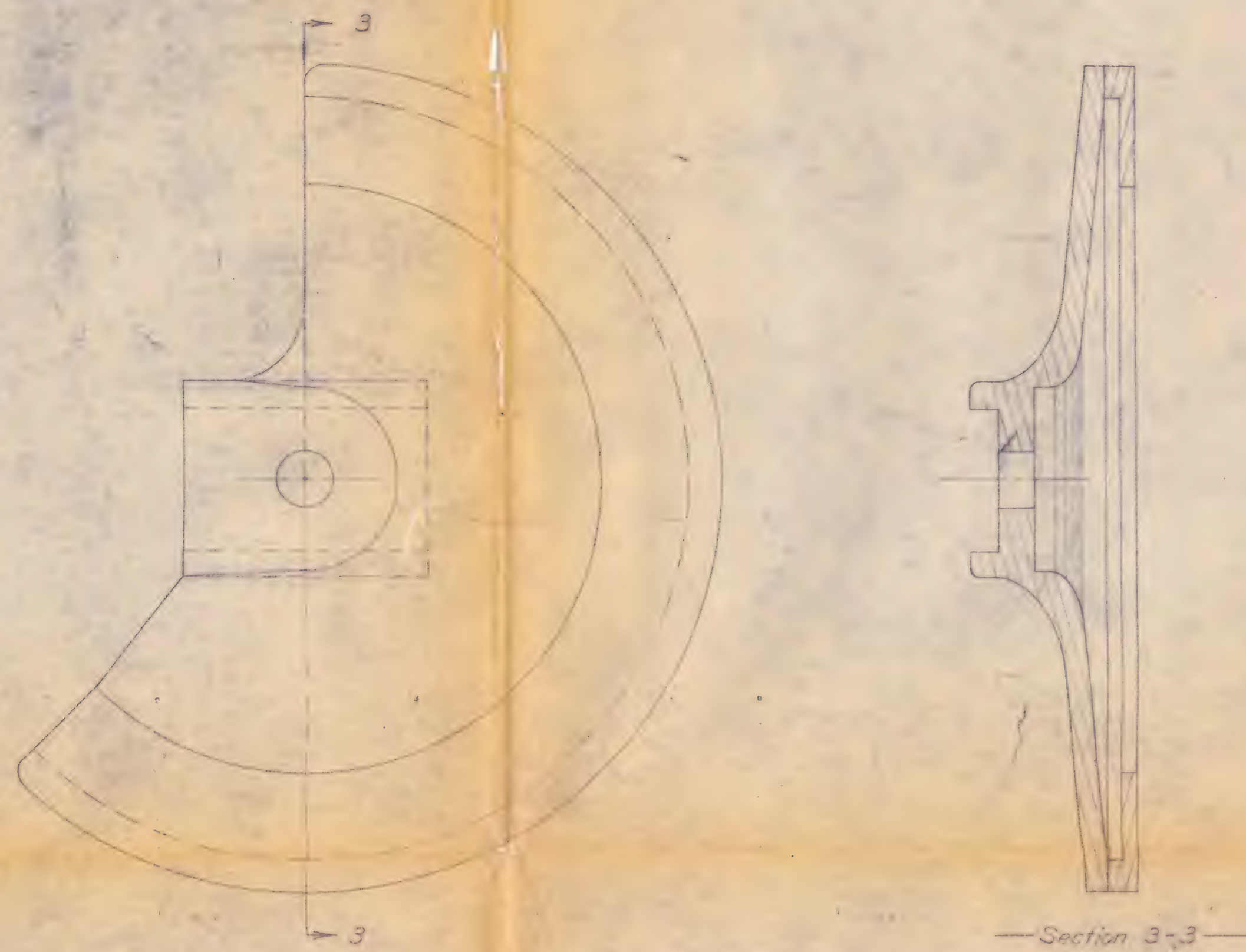
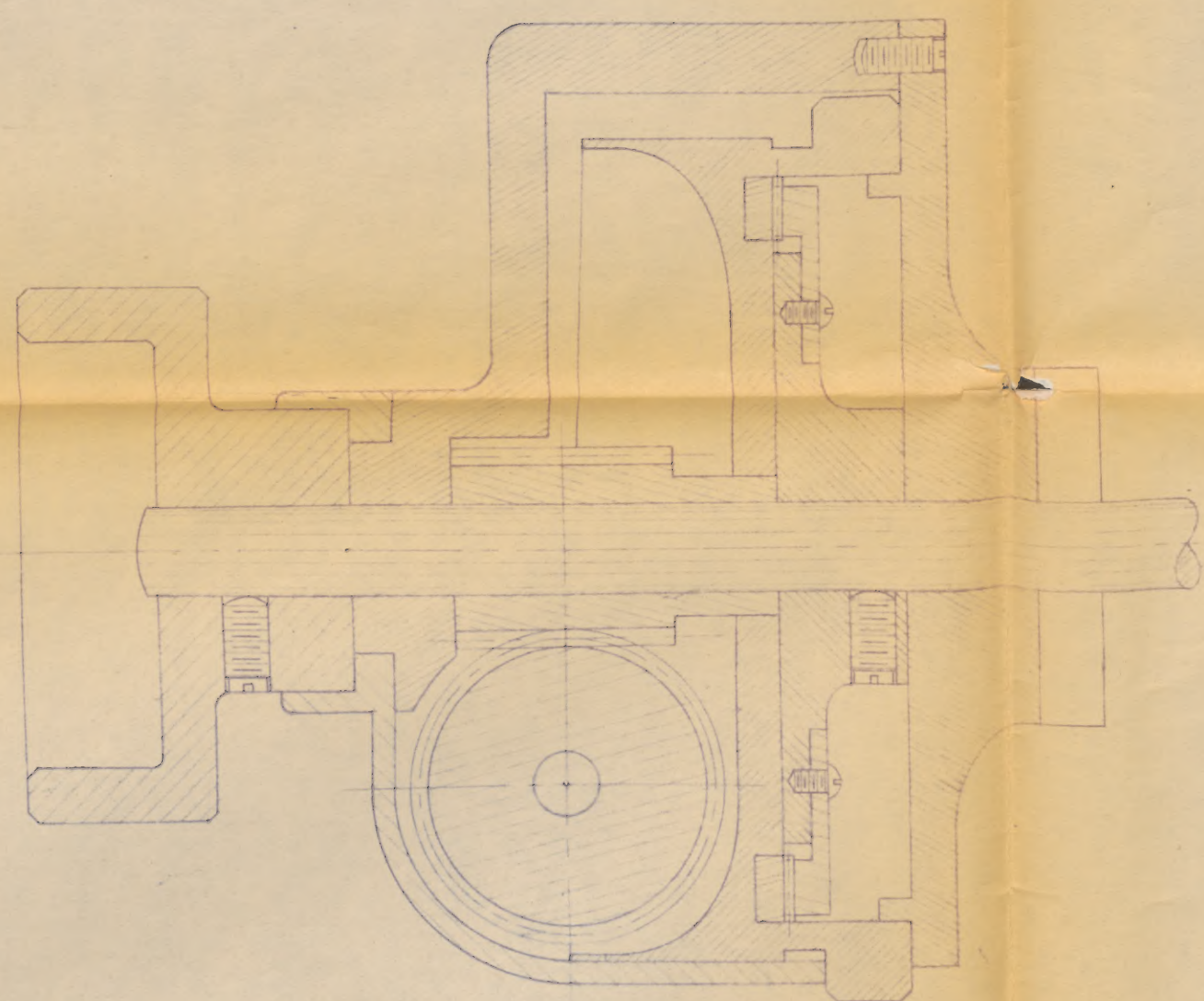
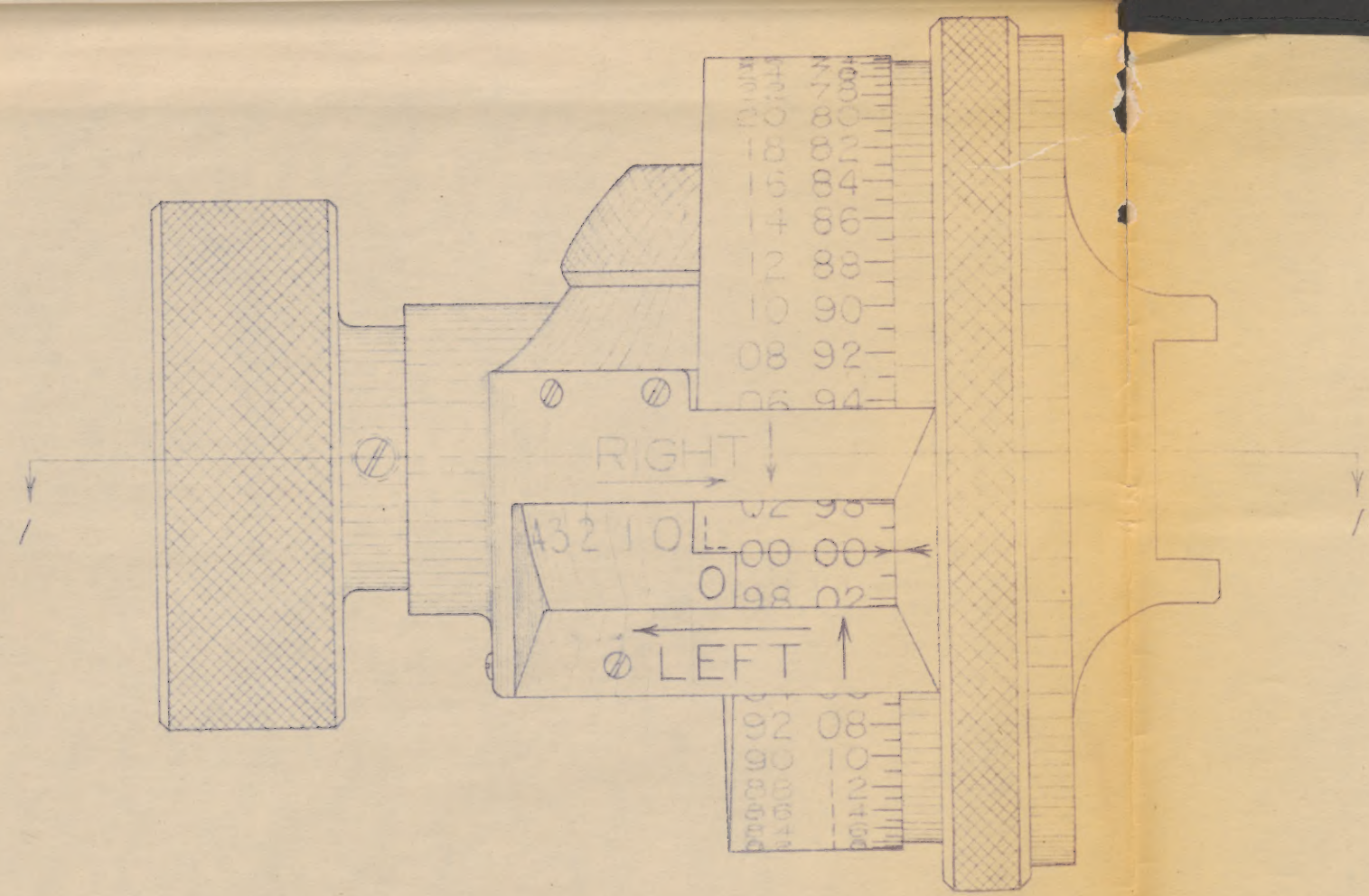
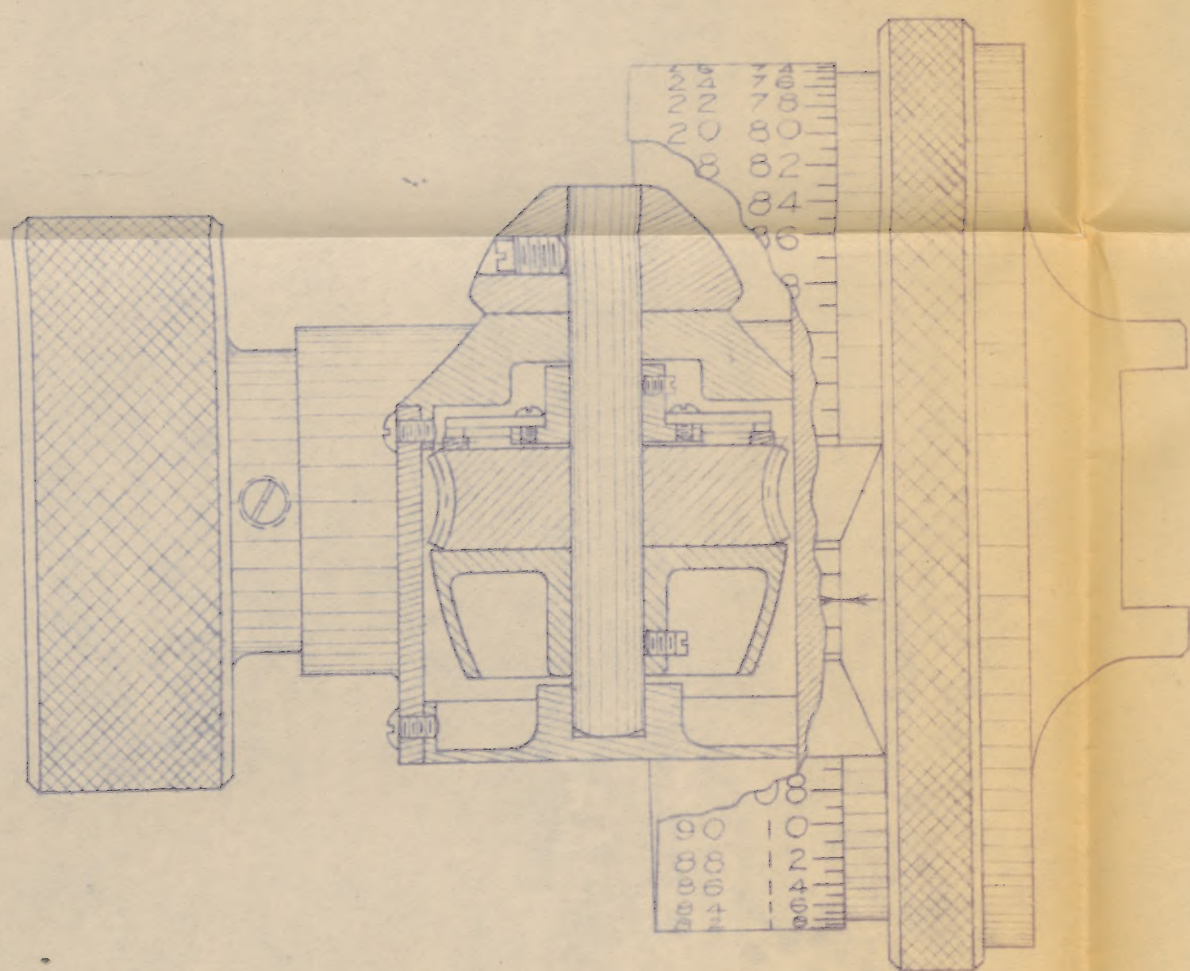


FIG. 7

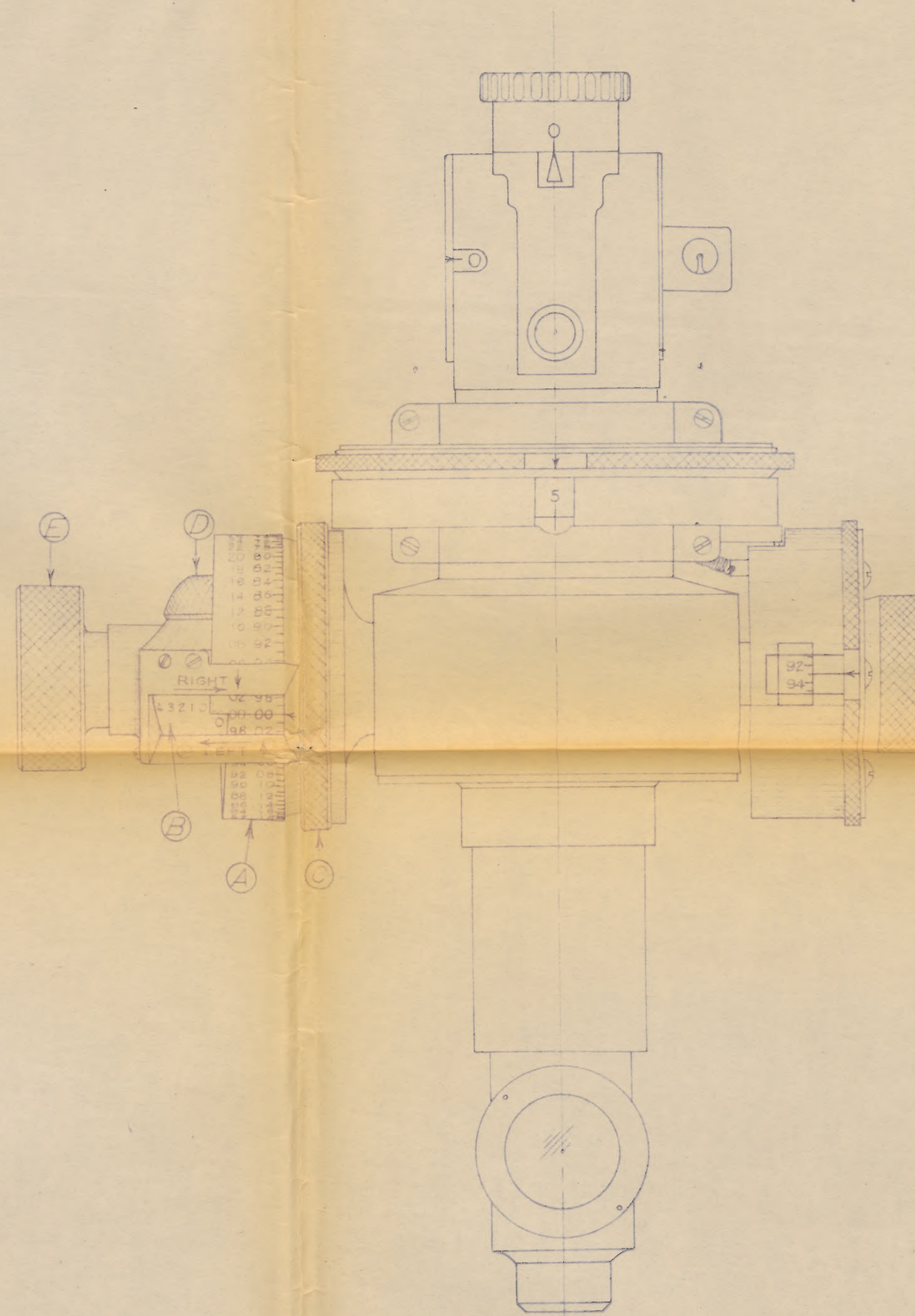
FLAT DIAL TYPE PANORAMIC TELESCOPE (DETAILS OF DESIGN AND CONSTRUCTION)	
ARMORED MEDICAL RESEARCH LABORATORY FORT KNOX, KENTUCKY	
LT. COL. F. S. BRACKETT	
SCALE - DOUBLE	DATE MARCH



Section 1-1



DOUBLE SCALE



FULL SCALE

FIG. 8

P 37

GUNNER'S AID FOR MODIFIED M12
PANORAMIC TELESCOPE

ARMORED MEDICAL RESEARCH LABORATORY
FORT KNOX, KENTUCKY

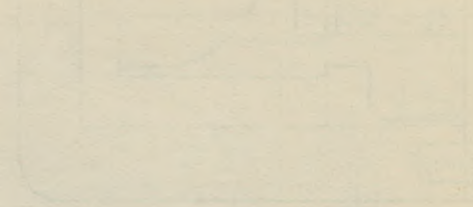
LT. COL. F. S. BRACKETT

SCALE AS SHOWN

DATE MARCH 22 1945

Incl #4

Fig 8



11/14

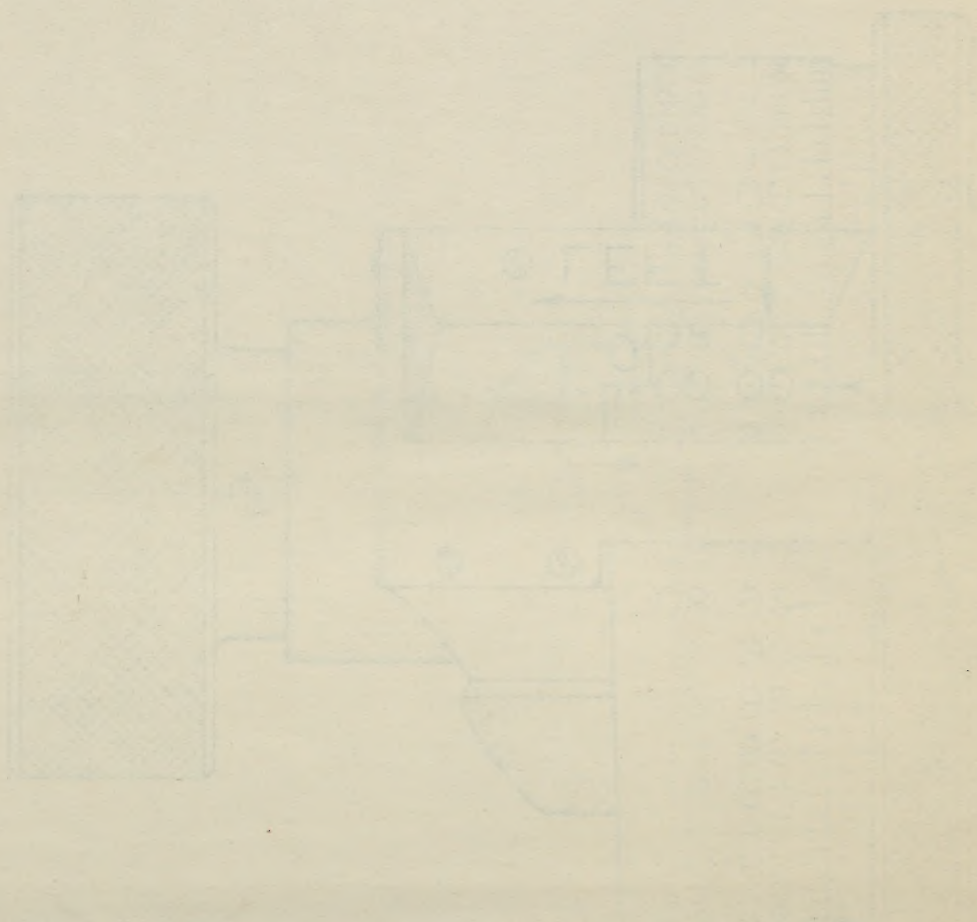


FIG. 9

RELATIVE OCCURRENCE OF 100 μ ERRORS
IN RELATION TO MICROMETER SCALE POSITION

PANORAMIC TELESCOPE M12

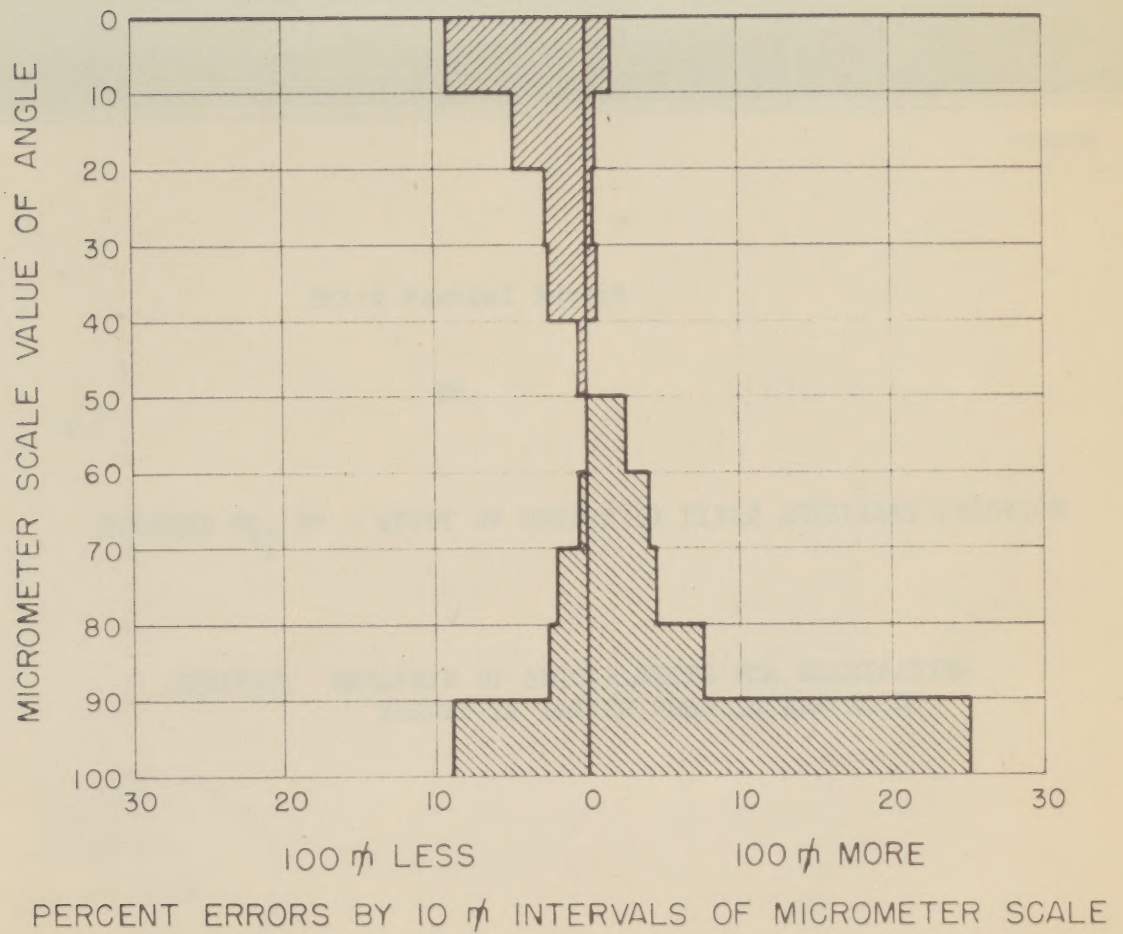
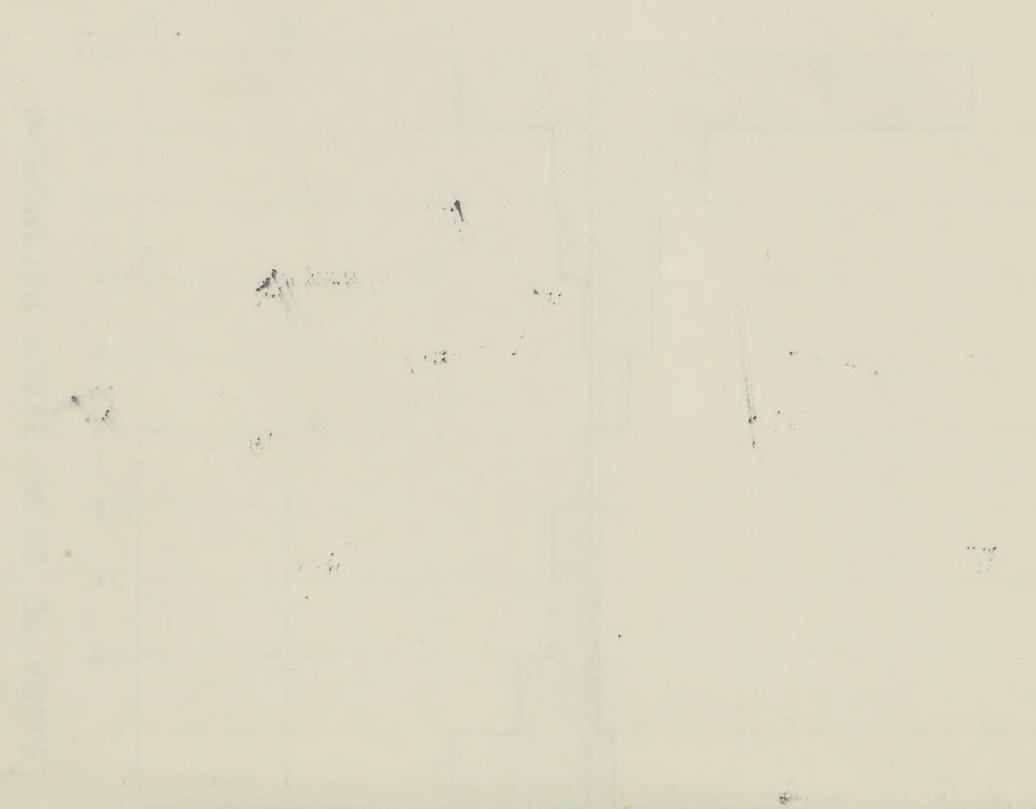


FIG. 9

GENERAL SCHEMATIC OF THE 100 W. ELEVATION IN THE 100 W. ELEVATION



SYNTHETIC 100 W. ELEVATION
 IN DETAIL TO MICROSCOPIC SCALE
 REGARDING OCCURRENCE OF 100 W. ELEVATION